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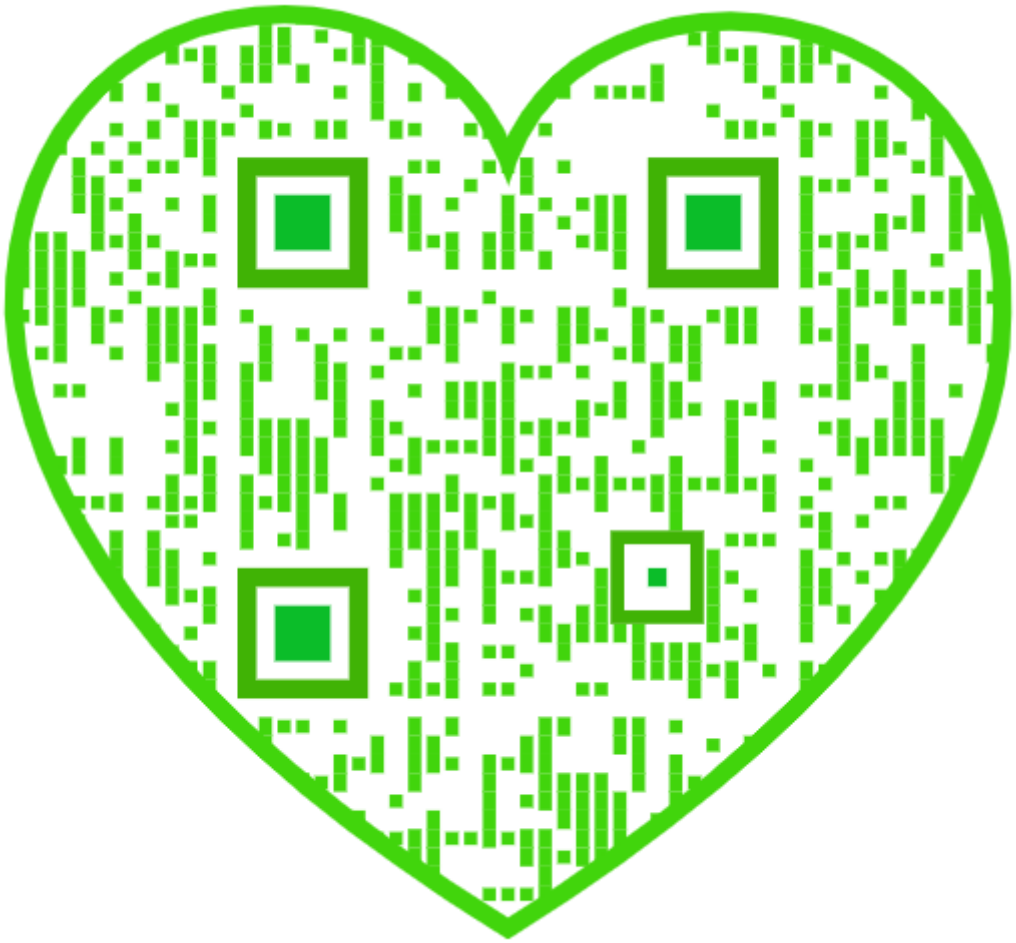

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Sewage Purification Plants

By J. W. Alvord, M. W. S. E.

From the JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS

APRIL, 1902

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SEWAGE PURIFICATION PLANTS.*

JOHN W. ALVORD, M. W. S. E.

Read February 5, 1902.

The literature of sewage purification contains very much that is theoretical rather than practical. It also contains a good deal that has emanated from the laboratory rather than from actual practice. We have elaborate reports by eminent commissions upon miniature experimental plants, and the subject loaded with the literature of proprietary claims and patented processes, the authors of which are quite lawless as to exact statement of fact. These reasons have rendered it very difficult for the student or layman to form any adequate conception of the advancement in this branch of engineering.

Added to the difficulties above enumerated, of recent years there has been a remarkable advancement in our understanding of primary principles involved. An advance which has rendered necessary the revisions of many excellent and well written volumes upon this subject by eminent authors, and published as recently as within four or five years.

The subject of purification of sewage has interested not only the sanitary engineer, but also the medical profession, the chemist, the bacteriologist and the municipal expert. The result of this has been that the language of this specialty has become replete with technical terms, drawn from these various professions, which cause it to be sometimes rather unintelligible. Moreover, as is the case with every art which is in a rapid state of advancement, new theories are constantly being propounded, so that the observer is often perplexed in his attempt to decide just how much of the art is safely or surely determined, and just how much is still in a theoretical stage.

Sewage purification plants labor under the difficulty that skilled expert supervision is fully as necessary in their operation as in their

NOTE. After the presentation of the paper, Mr. Alvord informally described about sixty stereopticon views of Sewage Purification Plants, completed or under construction, only a portion of which are here represented with brief description.

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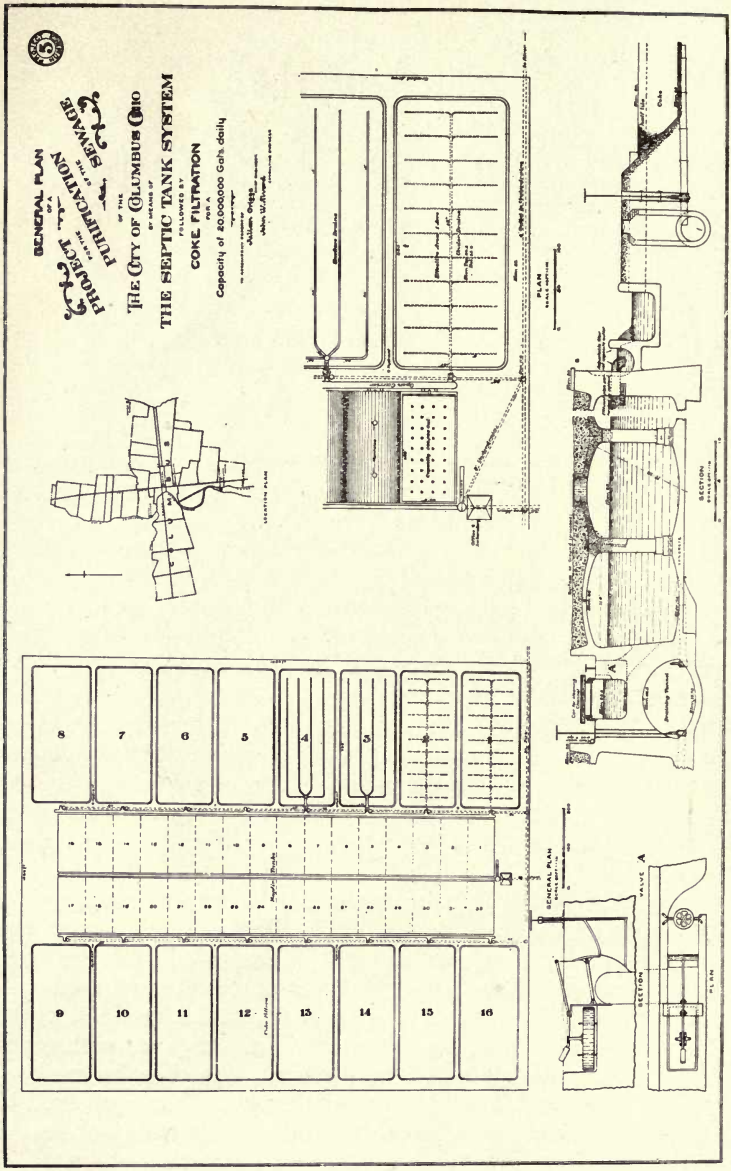


Original design of 32 Septic Tanks for Columbus, Ohio, in 1898, following closely English practice. Automatic control obtained by regulating device in combination with use of varying numbers of tanks.

design and construction. This is a condition that has not been recognized by the public at large and is only beginning to be apprehended by sanitary engineers themselves. Sewage purification works return no revenue for the investment, and therefore do not

enjoy the popularity for municipal purposes that a good paying water works plant always does. It is but natural, therefore, that those municipalities that have been driven to adopt such plants, either by due process of law or by threats of legal proceedings, find themselves unwilling or unable to properly maintain the works after they are constructed. And after a few years, during which the expenses of operation are cut down again and again, the plant naturally fails to give the expected results and as a consequence is condemned as inefficient in design. Especially was this the case in former years when the expenses of operation were so very great. The newer and more recent biological processes, connected with automatic operating devices, it is hoped will somewhat escape this difficulty. Still it is true, so far, that the necessity for skilled supervision is not yet obviated.

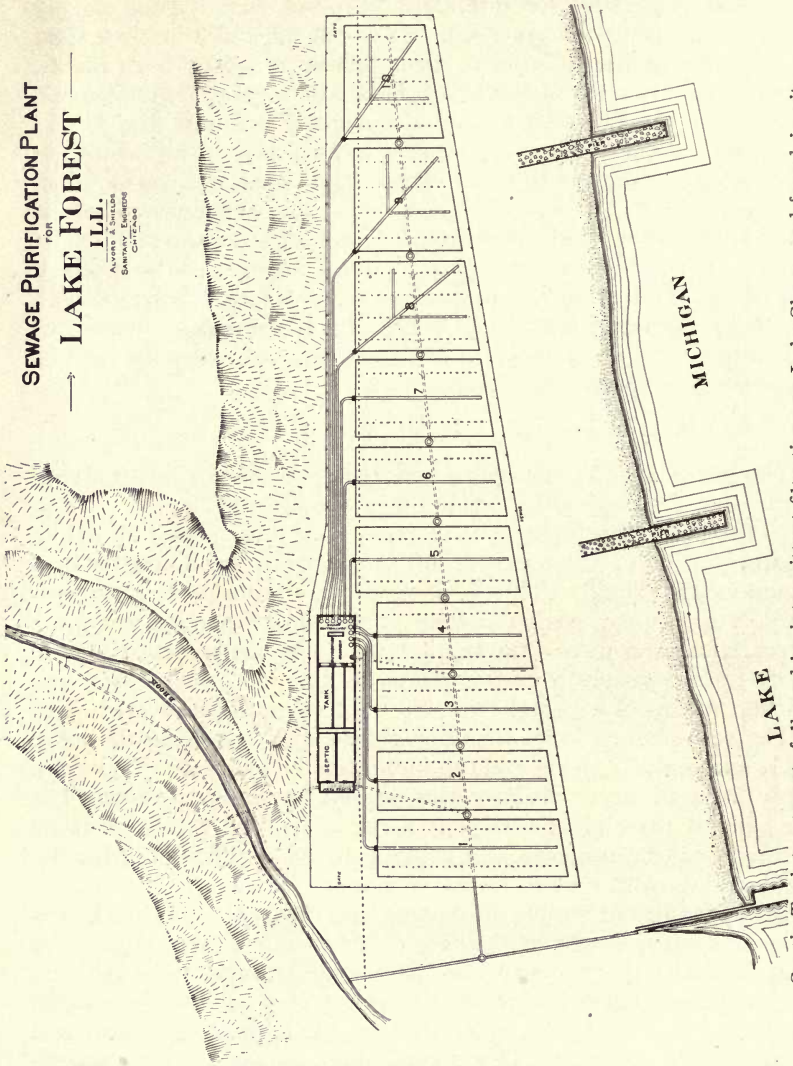
PRINCIPLES INVOLVED IN PRESENT PRACTICE.

The purification of sewage as now practiced most sucessfully requires that the process be divided into two stages:

In the first stage there is the necessity of eliminating all of the greater portion of the particles of suspended organic matter contained in the liquid. This is accomplished more or less successfully by screening, sedimentation, chemical purification, roughing filters, bacteria beds and the septic tank. At the present time the septic tank is generally considered to be the most economical and efficient means of accomplishing the first stage of purification.

The second stage of purification consists of removing the more finely suspended residue and the impurities in solution. There are many ways of accomplishing this, known by different names, but the general principle underlying them all is that the liquid to be purified must be brought into contact by wide diffusion at innumerable points with certain forms of nitrifying bacteria in the presence of a sufficient supply of oxygen and retained under such conditions a proper length of time for complete chemical change to be accomplished; this properly done, the liquid is found to be purified. Most of the methods by which this principle is practically applied involve intermittency of application of the liquid to the filter and its alternating areation. This second stage involves processes commonly known as broad irrigation, intermittent filtration, bacterial contact beds, filters with forced areation and continuous filters.

Sewage purification has had its origin and greatest development in England, where crowded populations located on insufficient water sheds gave rise to an incredible nuisance which would seem intolerable in our own country. England has for forty years past wrestled with the sewage problem, and it is safe to say that over one-half of the sewage of the United Kingdom today passes through



Septic Tank treatment, followed by intermittent filtrations on Lake Shore sand found *in situ*.
In operation since January 1, 1902. Capacity, about 250,000 gallons of sewage per day.

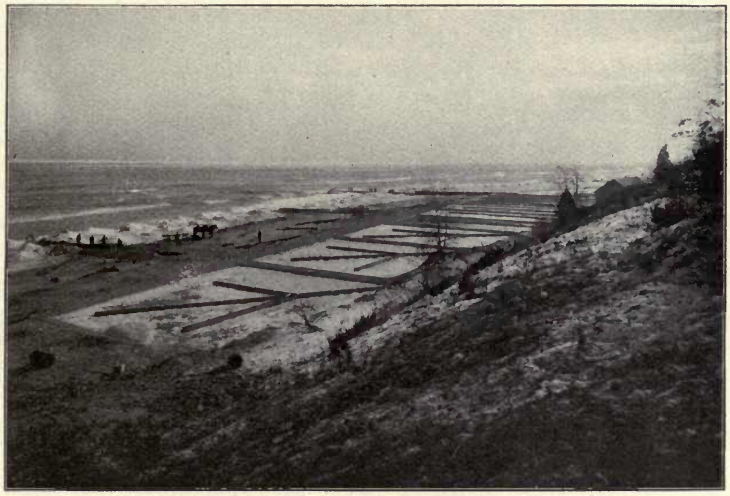
some form of attempted purification. It is but natural that England should have kept in the lead in this problem, and its most interesting recent developments have found their greatest appreciation in that country.

THE SEPTIC TANK.

Both in this country and in England in a number of instances reservoirs have been built prior to 1894 and operated as septic tanks without attracting general attention. The installation at

Exeter, England, in that year was the first plant to attract wide notice, although it is interesting to know that a member of this Society constructed a true septic tank at Urbana, in this state, simultaneously with the Exeter tank.

Broad patents have been issued to the promoters of English tanks in this country, covering the principle of light and air tight tanks with submerged inlet and outlet, but it is significant that the owners of these patents have never yet been willing to test their validity in court, and it is evident that should they do so, the claims of many prior installations might seriously vitiate their value. For this reason sanitary engineers are everywhere installing tanks of their own design. It has been shown quite clearly



General view Intermittent filtration beds, Lake Forest Plant, ¾ of an acre. Rate of flow, 300,000 gallons per acre per day, and upward.

that neither the exclusion of light or air nor the submergence of the inlet or outlet is necessary for the development of successful septic action. Many engineers prefer a form where these requirements are entirely neglected as giving the most satisfactory results; the ferment or septic action appears to go on in such tanks quite rapidly and the suspended matters in the sewage are dissolved as in air and light tight tanks.

The septic tank is not a complete system of purification in itself; only under the most favorable circumstances does it give effluents which are inoffensive. Generally the average effluent is both offensive and liable to cause nuisance, but the process effects one great change in the sewage—it breaks down the suspended mat-

ter, some of which disappears in the form of inoffensive gas, while another and larger portion is dissolved into solution. This is accomplished by a species of bacterial fermentation within the tank, and when the fermentation period is properly adjusted, and not too long prolonged, the effluent will be found tolerably free from suspended matter and in a condition when it is most easily oxidized by further filtration. The importance of this change in the character of the sewage from an economical standpoint is much greater than would be first perceived, for it is this first stage of purification that has always proved to be the most difficult one. Chemical precipitation, with all its expensive machinery, was invented for this purpose, but it does not accomplish what the septic tank ac-

View of Tank Building and Filter beds, Lake Forest. 10 Filter beds, 3,200 sq. ft. each, receive a dose of about 8,000 gallons once in 10 or 12 hours.

complishes in that it leaves the sludge problem unsolved and provides an effluent so loaded with disinfectant that it is not easily oxidized. Intermittent filtration alone has found its greatest difficulty in dealing with the suspended matters carried in the raw sewage, which, if turned upon the beds without preliminary treatment, rapidly forms a film upon their surface; this impervious crust would very soon render them useless if not removed from time to time. The raking off of this surface film and disposing of it effectively, in order to keep the beds up to their rated capacity, has always caused the most serious expense connected with intermittent filtration, and although an efficient supervision should keep the beds well cleaned, it is evident that a large portion of the time

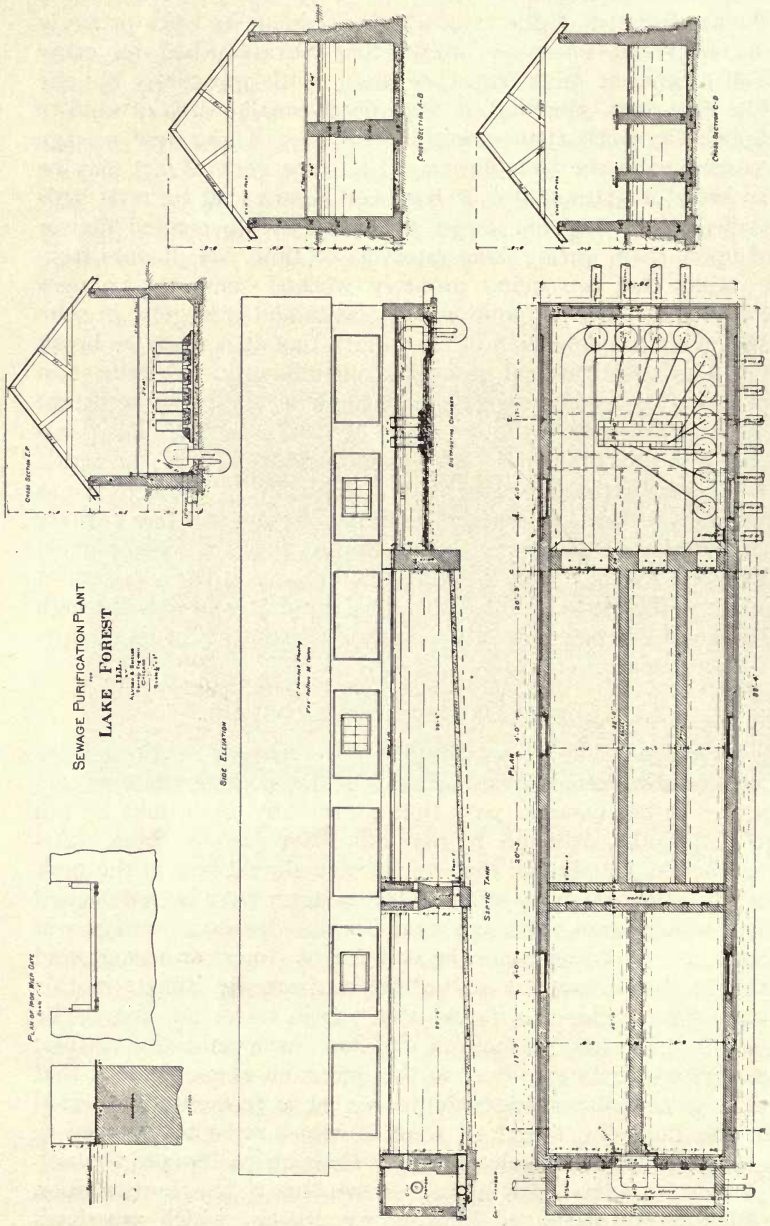
their rate of filtration will only be a portion of full capacity of clean beds. This leads to the necessity for an increased area, which involves increased outlay.

Effluents from a septic tank which is doing its work properly may be delivered upon an intermittent filtration bed for many weeks at a time at high rates of flow, with apparently but the slightest clogging—allowing a very much smaller area of sand to accomplish the work than would be the case if the raw sewage were turned upon the beds direct. The same general fact may be said of broad irrigation, and it has been shown that bacteria beds are injured by having too large quantities of suspended matter passed upon them during long intervals of time. Effluents from septic tanks that are being properly worked seem to be very easily oxidized. The organic matter contained is largely in solution and in such a condition of instability that it is ready to break down into its constitutional gases without difficulty. Nitrification sets in promptly and the passage through a single intermittent sand filter will usually leave but one or two per cent of organic matter in the final effluent. The economy, therefore, of the septic tank is not alone that no expensive machinery is required, or a large amount of labor to perform its function; nor is it due entirely to the fact that it eliminates into harmless gases a large portion of the sludge left in it, but it is also essentially in the fact that it enables the effluent to be filtered at very high rates of flow through small areas of soil or compactly constructed contact beds occupying but little space.

NEW THEORY OF SEPTIC TANK CONTROL.

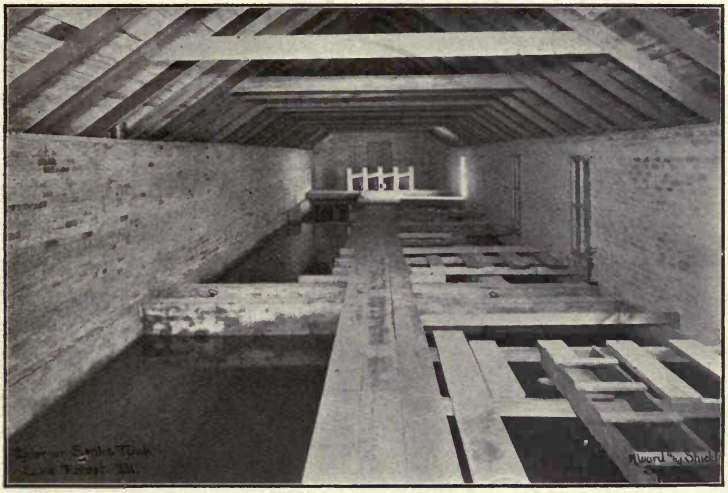
The septic tank has passed through the period of doubt and distrust and is now being carried along on the popular wave of enthusiasm. It has come to pass that almost any one thinks he can design such tanks, although he may only have read of them. Accepting the English dictum that the sewage should rest in the tank from 12 to 24 hours, many tanks in this country have been designed on this basis, ignoring the fact that English domestic sewage will often average about four times the strength of American sewage, and that the English climate is quite different from the climate in this country. The writer has found that septic tanks are not to be designed on haphazard principles, and has developed a theory from four years' practical experience in the operation of such tanks, that the particles of every sewage require a rest or fermentation period within the tank the length of time of which must be adapted to their temperature, their concentration, their character and the volume of flow. It has been clearly shown that if this fermentation period is unduly prolonged poisons are created which are detri-

mental to the life and activity of the anerobic bacteria. Such impairment of their vitality reduces their activity and fills the tank



Details Lake Forest Septic Tank, adjustment of fermentation period secured by five compartment system—Automatic distribution chamber included in building. Liquid capacity of tank about 60,000 gallons, Cost about $3,200.

with undecomposed suspended matter, which must be necessarily cleaned out quite often and produces an effluent which it is difficult to oxidize. On the other hand too short a fermentation period does not effect that degree of purification of the suspended matter which is possible and allows considerable suspended matter to be carried over onto the filters to their detriment, and also causes the tank to fill with sludge. The severe winter temperature of the northern states has been found to retard septic action, while the heat of summer accelerates it. This is a difficulty not so observable in England, where a warm, even climate prevails, and it is for



Interior of Septic Tank at Lake Forest. In foreground lateral trough for combining various compartments. In background automatic diversion chamber.

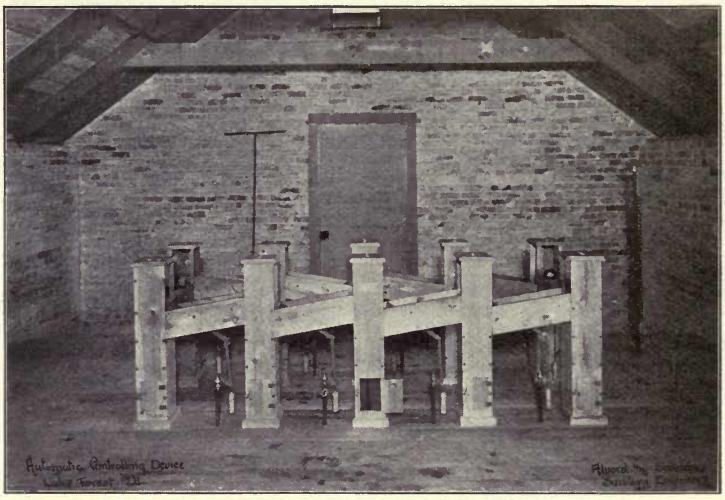
this reason that we prefer housing our tanks with a light brick building covered by a felt roof which shall equalize the extremes of climate.

The theory of a proper fermentation period requires that some adjustment should be made between the volume of sewage flowing into the tank and the capacity of the tank itself. It is evident that a tank designed for the sewage of 2,500 people, and which receives the first year of its work the sewage from only 500 people, has its fermentation period prolonged many times more than its designer intended. It is evident, too, the strength of the sewage may be increasing as more and more house connections are made with the sewage system, so that from receiving a small quantity of thin, weak sewage when first put into operation, in the course of two or

three years it may receive its maximum volume of strongly concentrated liquid. If now a winter of severe weather intervenes, retarding the septic action, and the alternating summer heats accelerate it, further complication ensues, and the perplexed public who begin, at times, to perceive an odor around the building and note that it has to be cleaned every month or so, lose faith in the original enthusiasm of its designer.

EXPERIMENTS ON SEPTIC TANKS.

Early experiments with coloring matter showed that with wide or deep tanks the flow of sewage through the tank was more rapid through a certain defined zone, and that in this zone a portion of the sewage remained in the tank only about one-third of the time



Lake Forest Plant. Automatic device for rotating contents of Diversion Chamber to filtration beds. Operation effected by rising and falling floats, a rolling ball and syphons operated by air valves.

that would be denoted by the ratio of the volume of the sewage flowing daily, to the capacity of the tank. It was felt that this difficulty should be overcome so far as possible by more skillful design.

The first tank our firm designed was proportioned for a 24-hour rest or fermentation period for the maximum flow of sewage, somewhat on the principle that one would load a gun so full of shot that something would get killed. The result was that with minimum flow an average fermentation period of over three days resulted, and the tank did not work well; probably portions of the suspended matters remained in the tank for weeks and it gradually filled.

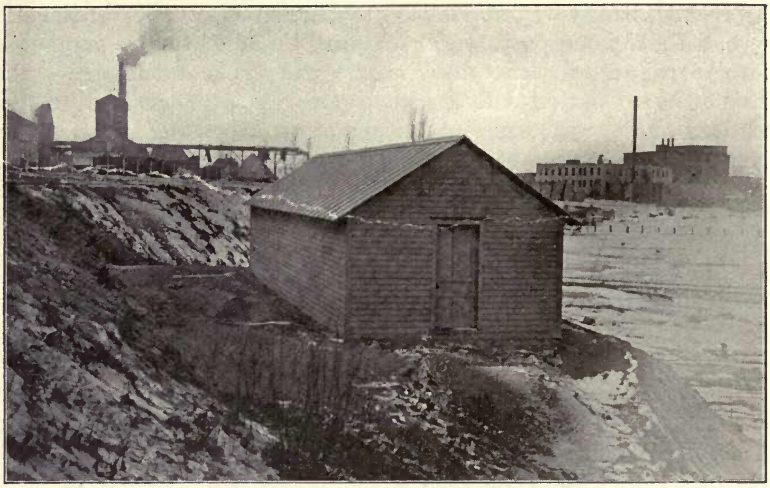
After much study we temporarily partitioned off portions of the tank with a light wood partition of matched board in such a manner as both to reduced its effective capacity and prevent the direct flow from inlet to outlet, with marked improvement resulting. Again sections of the tank were partitioned off and the direct path of flow from inlet to outlet still further retarded. Finally a result was reached in which the septic action seemed to equal the rate of inflow of suspended matter, and this condition was maintained for some months until cold weather set in, when the tank began to slightly fill again. About this time Prof. Talbot called our attention to the fact that the fermentation was much more rapid in summer than in winter, and it began to be seen that adjustment in capacity for varying conditions must be provided for.

The problem of preventing the direct zone of flow between inlet and outlet presented the greatest difficulty in originating new designs, and experiments showed that no arrangement of baffle boards was wholly able to overcome this difficulty. The best results were found to be obtained when the entering flow was subdivided into several separate streams in parallel compartments. By this means the rates between the volume entering a given tank and its total capacity could be somewhat equalized.

NEW DESIGN OF TANK.

In order to more thoroughly control the variations caused by increasing volume, temperature and concentration, a so-called elastic tank was designed for the City of Holland, Mich., having three long compartments which could be operated singly, in duplicate, or in triplicate, or continuously as one long tank. This form has proved to be capable of easy adjustment and well adapted to practical conditions, and in some of our more recent tanks five compartments of varying capacity have been introduced, which, when worked singly or in combination, allow almost any considerable fraction of the whole capacity to be utilized for the time being; this also equalizes the tendency for portions of the suspended matter to reach the outlet too early. The gates, troughs and chambers by which this manipulation is effected are simply and conveniently arranged, and render anything but skilled superintendence unnecessary.

In actual practice, it is believed that when a septic tank has its fermentation period properly adjusted to the strength, quantity and temperature of the sewage flowing into it, there will be a minimum deposit of undecomposed matter upon the bottom of the tank, unless cellulose or mineral matter is present in large quantities. If so, these should be removed by a preliminary chamber as much as possible. A great deal of misapprehension exists in regard to the



Septic Tank at Holland, Michigan, discharging effluent directly into Black Lake; built entirely of wood. Liquid Capacity, 60,000 gallons. Cost, $1,200. Completed in 1900. First tank using compartment system of control.

ability of a septic tank to consume the intercepted suspended matter. Statements are frequently heard that this is almost entirely consumed, and that the tank will proceed for years without any material increase in deposits. It may be possible that this is true in the case of a tank whose fermentation period is exactly adjusted and constantly watched, but so far as our experience has gone, and we now have some sixteen tanks in operation, the adjustment cannot be made so perfectly but that it is necessary to clean the tank at least once in a long while; therefore provision is made for flushing pipes from the bottom of the tank, by which excessive deposit can be removed.

It is believed that of the many tanks recently designed and constructed without apparent reference to the relation of capacity to flow, in some few of them happy accident has produced the right proportions. Such tanks are naturally pointed to with pride as being very successful, but as time goes by, if this theory is right, they may become unsuccessful through changes in volume, temperature or strength. In like manner some unsuccessful tanks may become successful ones. With the elastic tanks it is believed no such chances must be taken, and the designer, who should always superintend the operation of his plant for at least a year after it is put in operation, will be enabled by simply opening or closing a few valves to experiment for the first few weeks until he arrives at the proper fermentation period for the particular quantity or

quality of sewage which he has in hand, and thereafter by equally simple manipulation keep it in successful operation without rapidly forming deposits or passing an undue amount of suspended matter to the filters. The septic tank in good working condition, and which is not being overcrowded, should have from four to eight inches of thick scum over its entire surface. There should be no objectionable odor perceived within the building when standing immediately on the compartments, and none at all outside the building. The effluent is rarely without some odor and in appearance will often be slightly clouded, but the proportion of suspended matter in it should not be large if the tank is working properly.

CHEMICAL PRECIPITATION.

Of chemical purification, as a method of eliminating suspended matter in the first stage of sewage purification, it is sufficient to say that with the exception of a few rare cases it is already generally considered as out of date, as an economical and efficient process. Of the 19 chemical purification plants visited by the writer in England in 1888, only two could be properly called inoffensive and they were but recently built. Chemical purification has been humorously described by the late Col. Waring as "A method by which you buy chemicals and employ labor to mix them with the sewage, settle the sewage in expensive tanks, press the sludge thus ob-

Septic Tank at Danville, Ky., followed by intermittent subsoil filtration. Built in 1901. In operation since September, 1901.

tained in complicated machinery and after all have the sewage left on your hands, without having purified the water which originally contained it."

The writer has recently noticed an account of a chemical purification plant in England which was so offensive that legal proceedings were brought and judgment for damages obtained on account of the nuisance, by a land owner who resided five miles away from the plant.

The enormous expense of operating chemical purification renders it quite certain that at no distant day the largest portion of the plants of this character will be replaced by the septic tank, where the same work is accomplished with practically no operating expense. It is because of this fact that we see the present enthusiasm for the septic process.

THE SECOND STAGE OF SEWAGE PURIFICATION.

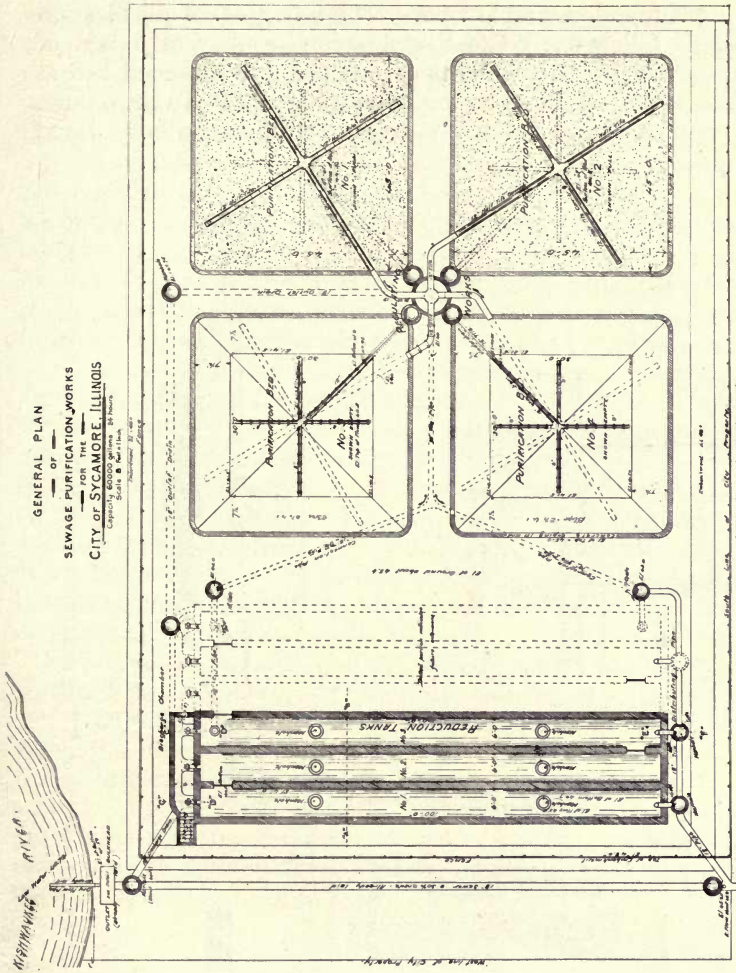
The second stage of sewage purification, by which the organic matter, which is largely in solution, is eliminated, is perhaps better understood in practice and presents less difficulties than does the first stage, already considered.

Broad irrigation and intermittent filtration have been known and practiced for many years and much data and information exist as to their details. Their chief difficulties have arisen from the accumulation of suspended matter upon the surface when the raw sewage was turned directly upon the land and the large areas required in consequence.

In England, where land near large cities is enormously expensive, they have endeavored for years to overcome this objection by improvements in chemical precipitation as a first stage, and attention was early attracted by the experiments of the Massachusetts State Board of Health, which showed the wonderful effectiveness of fine gravels in oxidizing the impurities of the sewage which dripped through it. As a result of further experiments along this line, sanitary engineers there developed the bacteria and contact bed as a method of consuming suspended matter as well as oxidizating organic matter in solution.

CONTACT BEDS.

The early English experiments on contact beds were summarized by the writer in a paper presented to this Society in 1898. A contact bed, it may be explained, is a water tight tank filled with fine or coarse particled matter and into which the sewage is regularly filled, rests for a few hours full and is then emptied. An interval then ensues in which the air, drawn down into the body of the tank by the removal of the liquid, thoroughly permeates its interstices and



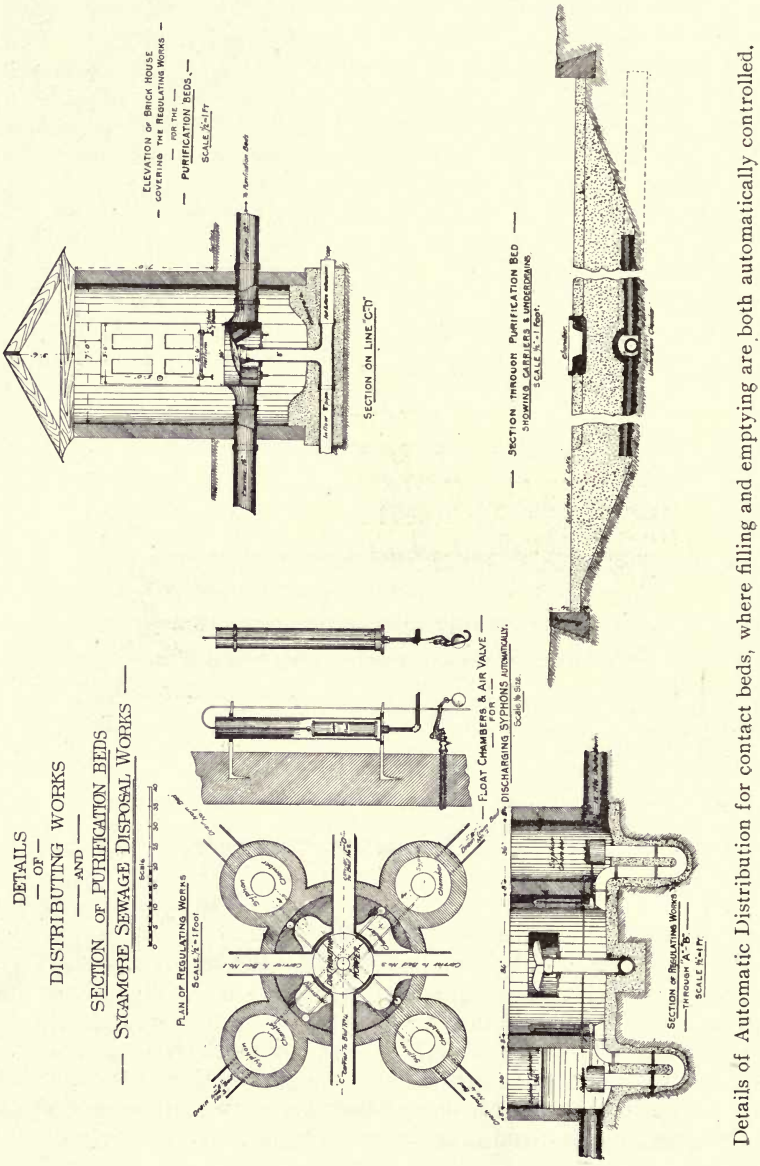
Plant for Purification by Septic Tank, followed by single contact beds of fine cinder. Septic Tank wholly below surface. Shows general arrangement of tank and distribution to beds through central chamber.

aerates it; the bacteria which swarm over every particle of the filter in the presence of such effective aeration oxidizes the organic impurities of each liquid dose as they successfully pass through the bed, and remove a large portion of the impurity.

A contact bed, as has been remarked by the writer elsewhere, resembles nothing else so much as a huge lung. The filling and emptying of the liquid in the contact bed corresponds to the inhaling and exhaling of a breath, and as the indrawn air in the lung oxidizes the impurities of the blood through the thin walls of its tissue, so does the entrained air and bacteria in the contact bed do its work upon the dissolved impurities in the sewage.

It has been found desirable where a high degree of purification is desired to follow one contact by a second contact in a bed of finer grain, emptying the contents of one bed into a second bed at lower grade, and if necessary the process can be repeated a third time.

Long continued trials of the coarser grain bacteria beds dosed


DETAILS
— OF —
DISTRIBUTING WORKS
— AND —
SECTION OF PURIFICATION BEDS
— SYCAMORE SEWAGE DISPOSAL WORKS —
ELEVATION OF BRICK HOUSE
— COVERING THE REGULATING WORKS —
— FOR THE —
— PURIFICATION BEDS. —
SECTION ON LINE C'D'
PLAN OF REGULATING WORKS
— FLOAT CHAMBERS & AIR VALVE —
— FOR —
— DISCHARGING SIPHONS AUTOMATIC. —
— SECTION THROUGH PURIFICATION BED —
SHOWING CARRIERS & UNDERDRAINS
SECTION OF REGULATING WORKS
— THROUGH A'B' —

Details of Automatic Distribution for contact beds, where filling and emptying are both automatically controlled.

with raw sewage only partially screened as a first stage of purification, have given rise to the fear that they are liable to gradual clogging with suspended matter, and require to be cleaned or washed, and perhaps rehandled; that this is positively necessary in all cases has not yet been fully settled; but if it is found to be the case, it is a question as to whether the cost would not be much less than the expense of labor in raking intermittent filtration beds upon which the raw sewage is turned. The whole question of the best method of treating suspended matters as the first stage has been for the present settled in favor of the septic tank, as has been already shown, and the proper field of the contact bed is now deemed to be the second stage or the purification of matters in solution.

For the second stage, the contact method has undoubted advantages, especially where sufficient area of sand bed is not available for intermittent filtration. If sand beds for intermittent filtration have to be constructed, contact beds will almost always be found to be more economical. But if the sand is in place or nearly so and of the right grain, and land is not too dear, intermittent filtration will generally be found the least expensive. Contact beds occupy much less area for a given capacity than do sand beds for intermittent filtration, but being of water tight construction this advantage is sometimes overcome by this expense.

Properly operated, intermittent filtration will give high rate of purification, much more so than single contact beds, but double contact beds will do nearly as well as a single intermittent filtration through sand of the proper grain.

The degree of purification to be attained by any plant is always a matter of local consideration. In some cases it is only necessary to abate a nuisance, in others a water supply must be protected; either can be accomplished, but the latter requirements will cost more to attain than the former.

AUTOMATIC CONTROLLING DEVICES.

With the advent of contact beds has come the necessity of automatic control of the filling and emptying period. The regulation contact beds have of necessity to be quite even and regular, and while the method of emptying and filling by hand has been adopted in some cases, automatic devices operated by the rise and fall of the liquid within the tank have become popular and a few have proved successful. There are several patent devices in England for this purpose and several in this country, some of which are being introduced at a number of places. These devices will undoubtedly work a great revolution in the care and management of sewage disposal plants. In intermittent filtration practice with raw sewage it has always been the custom, inasmuch as labor was necessary for raking

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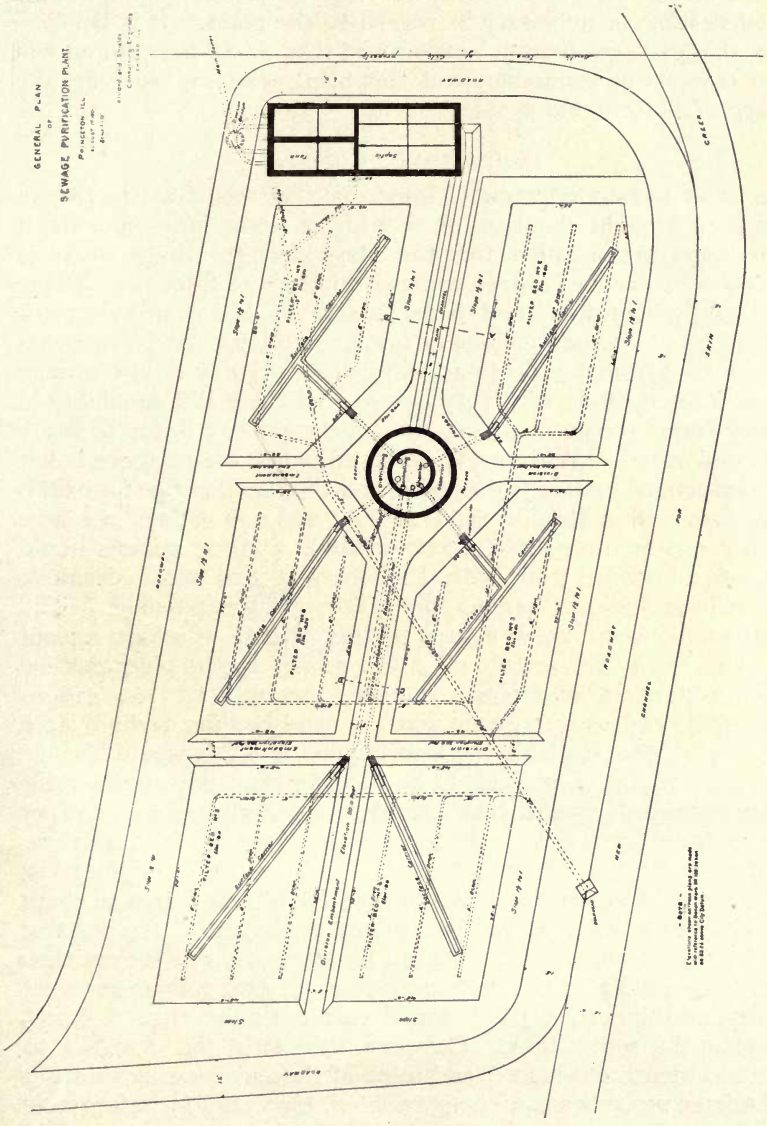
off the beds, to utilize that labor in rotating the flow from one bed to another, but with the advent of the septic tank and the discontinuance of the frequent rakings has also come the demand for automatic control for rotating the flow, and this is as necessary in intermittent filtration as it is in single or double contact beds. With the successful introduction of such devices, diverting the flow from septic tanks to secondary treatment by filtration in rotation, sewage disposal plants have become well nigh automatic, requiring little or no ordinary labor, and a minimum of skilled supervision so far as time is concerned. Not only this, but automatic devices make intermittent filtration more efficient than ever before by reason of

General view Septic Tank at Princeton, Ill.
Controlled by 5-compartment system. Liquid capacity, 60,000 gallons.
Cost, $3,500.

the regularity by which the process proceeds, and the independence which results from a disregard of certain fixed hours of labor. It is customary to operate contact beds with two hours resting full, thirty minutes to empty, three hours resting empty to aereate, and thirty minutes or so to fill, thus dividing the day into six-hour cycles and providing for four fillings per day. With strong sewage, eight-hour cycles and three fillings and emptyings per day are sometimes best. All this work may go on continuously with the automatic devices without regard to night or day, noon hour or work hour, fair weather or storm, and this regularity is found to be very desirable and essential to the economical workings of the plant, for by its

means the greatest possible effectiveness is obtained from any given contact bed or filter.

One of the plants designed by the writer's firm which was put in



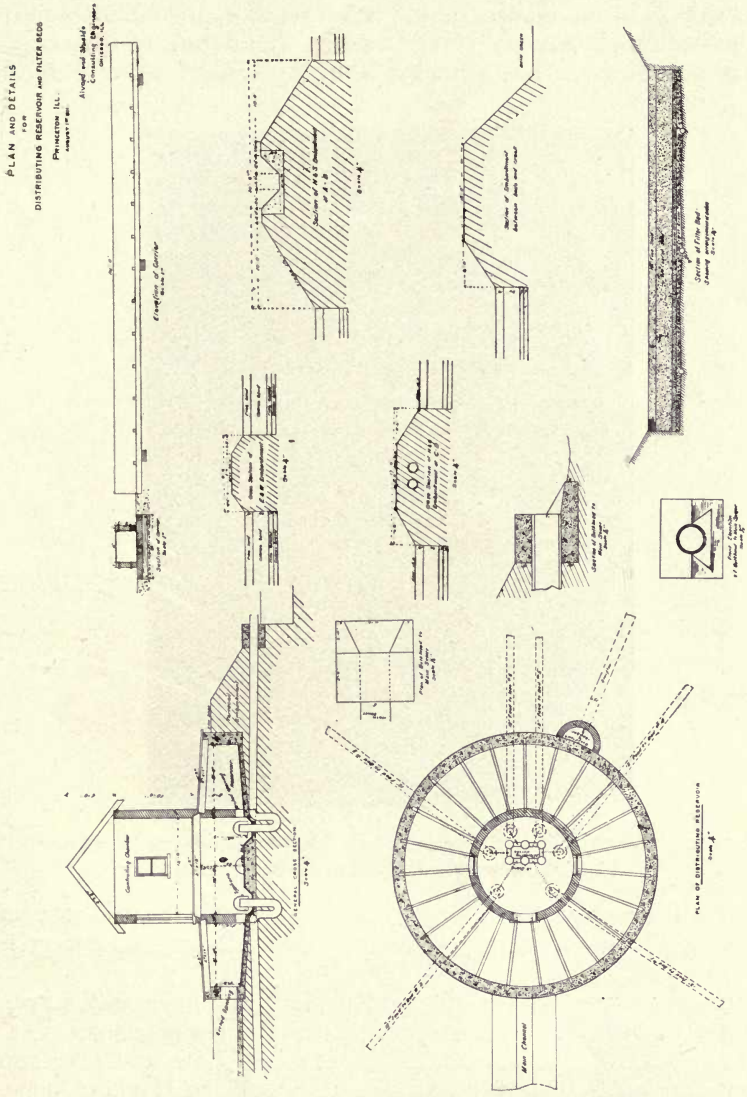
General arrangement of Plant at Princeton, Ill. Septic Tank followed by intermittent filtration with automatic distribution. Tank completed and put in operation November, 1901. Filtration beds not yet finished.

operation last summer has been working automatically ever since. It is visited for a few minutes twice each week to see that no mali-

cious mischief has been done and that nothing is out of order. On such visits the attendant notes the temperature, quantity of sewage which has been purified since his last visit (obtained by reading a counter on the automatic device), and notes such other points as may be interesting or necessary in regard to the plant. It is believed from the past six months' experience that $100 per annum will cover the cost of maintenance of this plant, which is purifying the sewage of about 2,000 people.

COMPARISON OF COST.

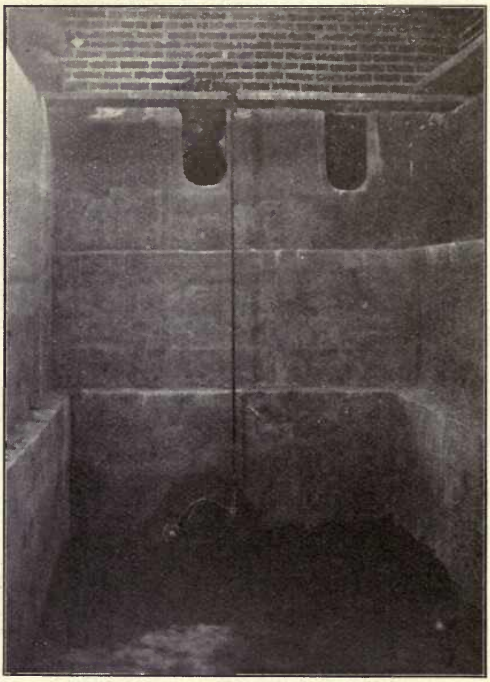
In order to fully appreciate some of the modifications which have been brought about in the filtering of septic tank effluents, it is necessary to remember that the Massachusetts State Board of Health experiments have shown that in order to filter raw sewage successfully upon fine sand beds, an acre of bed is necessary for each 16,000 to 20,000 gallons of sewage per day. With somewhat coarser sand from 30,000 to 40,000 gallons per day of raw sewage can be filtered, while with very coarse sand there is a possibility of passing from 100,000 to 150,000 gallons per day if the beds are kept well raked. With septic tank effluents where there is but little suspended matter to deal with, and the liquid is ripe for oxidization, even with quite fine sand at least 200,000 gallons per acre per day can be filtered, with coarser sand, 350,000 gallons would be a safe allowance; while with the coarsest and most desirable sand at least 500,000 gallons per acre per day is possible. The difference between these figures is this, that if you have a plant that must purify the sewage of 2,500 people by the older method of intermittent filtration alone, you would require (at 100 gallons per capita) not less than seven acres of sand bed for medium sized sand, and if the available sand was quite fine this would become 14 acres. If the sand had to be brought from any considerable distance the beds would cost complete not less than $10,000 per acre, or from $70,000 to $140,000 for the plant. Now, considering the substitution of the septic tank preliminary to the filtration, and you would at once reduce the cost for filtration area to about three-fourths of an acre, and you might easily afford the coarsest sand brought from a great distance for the beds, which even then could be worked at a rate not exceeding 300,000 gallons per acre per day, and the entire plant would cost not more than $16,000, including the septic tank. Compare this with the $70,000 to $140,000 mentioned before, and some of the enormous advantages of the later processes can be appreciated, especially in unfavorable localities. Not only in first cost, but also in operating expenses, simple intermittent filtration alone would cost at least twice if not three times greater than that necessary for the septic-tank installa-



Automatic Diversion Chamber at Princeton, Ill., rotating effluent from Septic Tank upon 6 Filter beds.

tion. Such a comparison as this I have just described is not at all uncommon, and is simply revolutionary in its results. It permits cities to own and operate sewage purification plants to whom it has been heretofore impossible. It allows plants to be built in localities where every advantage is lacking, and it permits the problem to be brought within workable limits for the largest cities of this country. In bacterial contact plants the results are still more

favorable as to the rates of flow. With septic tanks effluents most of these contact bed plants are worked at the rate of 500,000 to 750 000 gallons per acre per day, with the same rates of reduced



Interior of Septic Tank at Princeton, Ill., before admission of sewage. Initial compartment inlets and sludge valves.

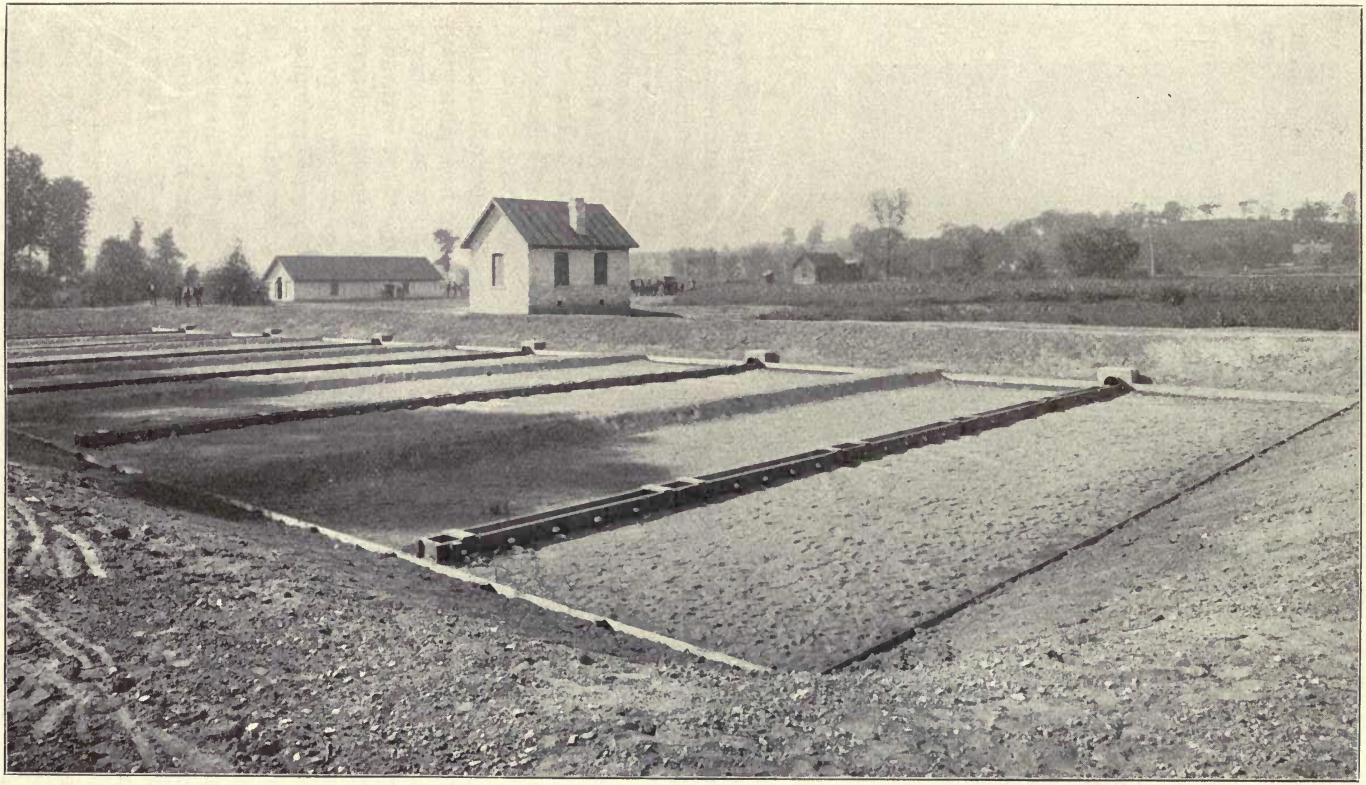
cost for maintenance, and it is questionable whether a rate of 1,000,000 gallons per acre per day for dilute American sewage is not fairly practicable.

Already the city of Manchester, England, has under way a project for the purification of the sewage on these new principles, costing $1,150,000. The city of Leeds will soon follow, and over 200 projects are on foot for cities of less population in England alone. We shall watch these experiments on so large a scale with unusual interest.

DISCUSSION.

Mr. Finley—How high are those beds at Lake Forest above Lake Michigan?

Mr. Alvord—The surfaces of the beds are about six feet above Lake Michigan, and of course they are thoroughly drained by a



General view of Plant at Wauwatosa, Wis., taking sewage from population of 3,000. Put in operation in August, 1901 Cost, about $6,000. Septic Tank followed by intermittent filtration with automatic distribution.

main underdrain, with numerous branches. One of the difficult problems of this site was to prevent the beds from being injured by the wind blowing along the beach, which tends to fill the beds with fine sand, so that they become flooded. We are constructing a very high board fence, which we think will prevent this trouble.

Mr. Francis H. Bainbridge—I would like to ask Mr. Alvord if these sand beds ever have to be cleaned or replaced when used for filtering purposes?

Mr. Alvord—They may have to be surface cleaned, but not replaced. So far as intermittent filtration has been known and practiced for the last dozen or fifteen years, there has been found to be no necessity for replacing the sand of the beds. There is necessity, however, of loosening the surface once in a while, which is generally done by raking off and and removing the surface flake or crust, if any; with the septic tank effluent the raking has become very much less burdensome.

Mr. Finley—Mr. Alvord, I believe you said that the plant for Princeton cost $3,000, with a population of 4,000. What is the cost of the maintenance of that plant?

Mr. Alvord—The filter beds have not yet been constructed in that plant, and of course we do not know what the maintenance would be. In our Wauwatosa plant, judging from the run which it has had so far, we think $100 a year would be a very ample figure to estimate on, and that is providing for the sewage of about 2,000 people. The first cost of that plant was a little over $5,000. The first cost of the Lake Forest plant was $8,000. The total cost of the Princeton plant, when it is completed, will be about $6,500.

Mr. Torrance—What happens to those sand filters during the winter months? For instance, such weather as we had yesterday.

Mr. Alvord—Sewage in process of dissolution is undergoing a chemical change, which gives rise to heat, and that heat is thrown out into the sand beds. It is generally sufficient to melt them if they are already frozen. It keeps the interior of the septic tanks quite warm. In fact, the men completing our Lake Forest plant were accustomed to eat their lunches in the septic tank, after it was in operation, that being the warmest place they could get. The Lake Forest beds were quite well frozen before the sewage was turned onto them, but after a very few days the main part of the frost, which perhaps was two feet thick, disappeared. The tendency is for a light crust of ice or snow to form on the top of the beds, but underneath that crust the filling and soaking-in process is going on all the time, even through the very severely cold weather.

Prof. A. N. Talbot—I have been very much interested in Mr.

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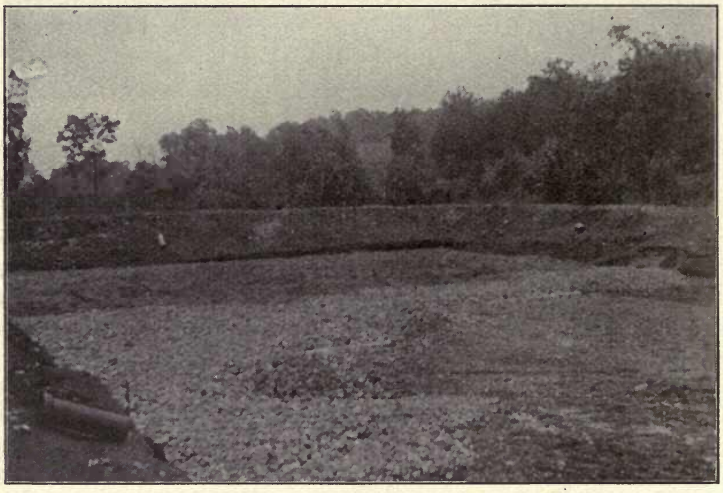
View of construction of Septic Tank at Wauwatosa, Wis.
Framing of forms for concrete work.

Alvord's presentation of the details of the purification plants which he has constructed, and he has certainly had very valuable experience and has constructed very successful plants. As he has stated, many changes in ideas concerning methods of purification have been made in the past few years, and while a great deal has been learned concerning the processes of purification, many matters remain unknown or are yet in dispute. It would not be strange, then, if I should differ with Mr. Alvord in regard to some details of the methods to be used in such purification or in the explanation of the action of processes, and of the principles involved in this purification. However, it does not seem best to take up this matter at this time. It seems, though, that the question of the use of terms to be employed might be discussed a little. In a subject as new as this it is not strange that there should be differences in the use of terms, and it is well to attempt to start a usage which will be systematic and not misleading.

It has seemed to me wise to confine the use of the term "contact bed" to those beds in which there is aerobic action in the purification of the sewage; that is, to those beds in which air is freely admitted and in which the sewage has been sufficiently cleared of organic matter in suspension to permit this aerobic action to take place. In a paper given by Mr. Alvord a number of years ago, the coarse bacteria bed was described. These beds were filled and emptied in much the same way as the ordinary contact bed, except that raw sewage (still holding the suspended organic matter) was

applied. Between the time of emptying and filling, little opportunity was given for air to reach the interior, as the retained organic matter and organic growth prevented easy access, and this and the quick consumption of the oxygen reaching the interior formed conditions which made the bacterial action mainly anaerobic. There was then little effect on the matter in solution, and the effect was similar to septic action. I think such a bed should retain the name "coarse bacteria bed," and that the term "contact bed" should be confined strictly to what was formerly known as fine bacteria beds. The contact bed, then, takes sewage from which most of the suspended matter has been removed by some process and acts upon the finely divided matter and upon that in solution.



Construction of Intermittent Filter Beds at Wauwatosa, Wis.
First layer of gravel being spread around underdrains.

Its action is mainly aerobic. In this connection it may be said that it seems to me that the purifying action of such beds is mainly during the time in which the sewage is held in the bed.

In passing it may be added that coarse bacteria beds which were in operation at Sutton, England, and experimental beds at Manchester and Leeds have proved to be not very successful, as they became clogged and had to be cleaned.

In the same way with intermittent filtration. It seems to me the term "intermittent filtration" of sewage should be used for that process where the sewage is applied intermittently and is distributed throughout the depth of the bed without at any time completely filling it.

As Mr. Alvord knows, I have also objected to the term "fermentation" or "rest period" in describing the capacity of septic tanks. The term is misleading in that one is likely to think that the sewage actually remains in the tank during the time indicated. Of course the matter in solution, the liquid which passes through, is changed to no great extent in the passage through the tank. As stated in the paper given before this Society some time ago, it seems to me that the capacity of these tanks is limited or governed by the area of the surface, and by the time taken to change the organic matter in suspension which is left behind in the septic tank. That is to say, if the flow through the tank is slow enough, there will be a subsidence or sedimentation which may be sufficient

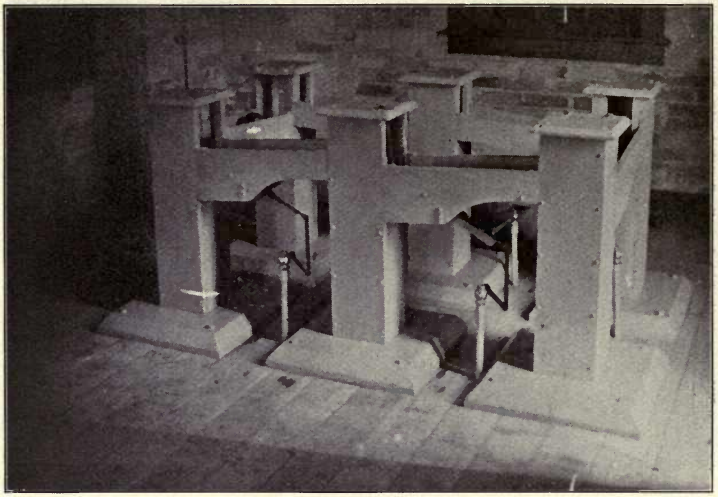
Construction of Automatic Diversion Chamber at Wauwatosa, Wis.
Setting the syphons in the bottom of the chamber.
Each bed has an independent syphon and connection.

to retain the suspended matter, even with a relatively considerable flow, but this retained suspended matter must be allowed considerable time for the operation of the bacteria, and if this exposed surface becomes coated over by other organic matter before the bacterial action is well under way, as would be the case where the tank is too small, the effective action of the tank would be reduced, and the tank would fill up rapidly. To avoid a possible misconception of terms like "fermentation" or "rest period," the capacity of the tank may be expressed in terms of the number of hours' flow of sewage, as, for example, a tank of cubic capacity equal to eight hours' flow of sewage.

Concerning elastic tanks, it should be stated that the size of tank may vary within considerable limits without seeming to affect the effluent. For example, experiments made in Leeds, Eng.—not laboratory tests, but on tanks of 250,000 gallons capacity—showed very little difference in results obtained with tank capacities of twelve hours, twenty-four hours, and forty-eight hours' flow of sewage. This of course was strong sewage.

Mr. Finley—This question of sewage purification being in such a condition of evolution, I have wondered whether it is a good investment for a village to spend very much money on these systems.

Mr. Bainbridge—If they do not spend the money, then there will be no further evolution.



Automatic Ball Controlled Device operating six intermittent filtration beds at Wauwatosa, Wis. Has been in successful operation since September, 1901.

Mr. Potter—It seems to me the best thing to do is to adopt the best method now available and then when improvements are made, incorporate them later. Most villages are compelled to take some action by the existence of serious nuisance, and often they are driven into it, by threats of legal proceedings.

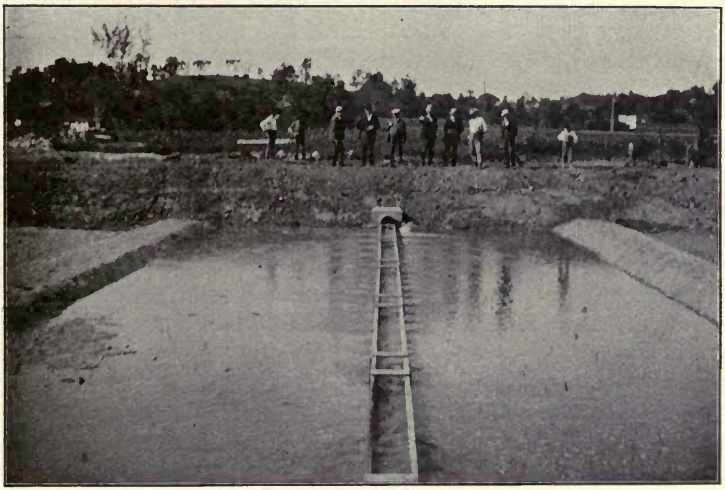
Mr. Finley—If I remember rightly, the City of Madison put in some arrangement for the treatment of sewage which was not very successful.

Mr. Alvord—They let a contract to a proprietary company for a chemical purification plant, with a guarantee, which was not suc-

cessful, but have substituted for it a septic tank with contact beds designed by a competent sanitary engineer, which I think is doing very well.

Mr. C. D. Hill—What would the effect be to lose the matte that forms on the surface of the tank, by removal of the baffle boards?

Mr. Alvord—Our observation has been that baffle boards are not absolutely necessary and that the matte will stay there, even without them, and in so far as it is a question of whether it brings conflict with any patent claims, we have decided, in one of our plants, to leave the baffle boards out temporarily. We do not always do that, but we did in this case.



Distribution of Septic Tank effluent upon intermittent filtration beds, at Wauwatosa, Wis. View taken 4 minutes after discharge in diversion chamber. Dose, 6,000 gallons.

Mr. Bainbridge—What is the action of the matte in the septic tank?

Mr. Alvord—There forms on top of the tank a scum, which consists of the residue from the suspended matte in the sewage. The particles of organic matter as they enter the tank are attacked by the bacteria in the tank and certain gases are liberated from them; this causes the particles to rise to the top, or, if the gases are not liberated with sufficient rapidity, they may drop to the bottom, and either at the top or bottom the remains of these suspended particles, consisting of the more refractory portions, together with fibrous and cellulose matter which are undergoing this process of

dissolution, form a coat of matter, and, as Prof. Talbot has pointed out, it is desirable that there should be a large surface, so that these particles may be as thoroughly dissolved as possible before they become covered by other particles.

With reference to the Professor's allusions to our different ideas about the "fermentation period," I may say that it seems to me it is largely a distinction without a serious difference. As I understand it, he thinks the area of this matte and the size of the tank are the vital questions—that they should be sufficiently ample so that the suspended matter should not cover them too rapidly, while my idea is that the particles of suspended matter entering the tank must remain within the tank a period which I term the "fermentation period," during which they must be dissolved into their constituent gases or reduced into solution. I do not see very much difference, myself, between the two theories, but if there is any, we will have to work it out together.

Prof. Talbot—I did not intend to attach any special importance to the calculation of this area, especially as with the usual depth of tank its capacity will be proportional to this area. As Mr. Alvord has just expressed himself, I should want to express myself as not agreeing that the time period of the passage of the sewage through the tank is equal to the actual period of fermentation. In fact, I have shut off the flow entirely from an overdosed septic tank in order to get rid of accumulated organic matter, and after a week have found the condition of the tank materially different from what it was at the beginning. Evidently the period of passing through the tank may not be the period required for bacterial reduction. My objection to the use of the term is that it may lead one to suppose that this period is the time which the sewage remains in the tank, and that it is identical with the fermentation period.

Mr. Finley—Would it not be the case that a small tank, which we will say takes a large volume of flow, would naturally fill with these undecomposed particles of suspended matter, while a tank which might be very ample in capacity would not be satisfactory?

Prof. Talbot—It is not a question whether enough area or capacity is being used, but what term should be used to describe the ratio between the capacity of the tank and the number of hours' flow of the sewage going through the tank.

Mr. Alvord—We have been driven into this theory largely because tanks which seemed to be too small filled up, and also tanks which seemed to be too large filled up. By partitioning off those tanks which were too large we get a capacity from which the surface matte remains only four or five inches thick. There is no further accumulation. Now there seems to be an ad-

justment here between the amount of particles which entered with the flow and were fermented and the capacity of the tank, and I have unfortunately selected "fermentation period" as describing that ratio. May I ask the professor what term he would prefer?

Prof. Talbot—Let me say first that I am not disagreeing with Mr. Alvord's statement that a suitable size of tank should be used. I have no term to propose other than to state the capacity of the tank in terms of the number of hours' flow, viz.: instead of eight hours of "rest period" or "fermentation period," use "the cubic capacity of the tank equals eight hours' flow of sewage."

Mr. W. G. Potter (by letter)—In the discussion of Mr. Alvord's paper on Sewage Purification, the question of the effect of cold weather upon the septic method of purification, and of possible freezing of the liquid, was touched upon.

In regard to the latter point I wish to submit the following:

It is a fact self evident to all that chemical action of any kind develops or causes heat. Chemical action of course is progressing in the septic tank, in the contact beds and in the sand beds, and experiments show that the heat produced in the septic action is sufficient to keep the temperature throughout about the same and is often sufficient to raise the temperature of the effluent higher than the original sewage.

In the report of the Massachusetts State Board of Health for 1898 in coke filter bed No. 103, which was used for the full twelve months, the entering sewage had an average temperature of 58 degrees and the effluent 59 degrees.

In sand bed No. 116 of same report, the use of the bed was begun in September, with a loss of temperature for several weeks while nitrification was not in full operation, but the whole period from September to January showed a gain of 1 degree in temperature.

In 1899 report of same authorities in septic tank with the record of ten months from March 1st to January 1st, the temperature showed an average gain of 1.2 degrees for the entire period. The lowest monthly average temperature of original sewage was 46 degrees, while the lowest for septic tank effluent was 48 degrees Fah.

In 1900 report the septic tank again shows a gain of 1 degree for the yearly average, the lowest average temperature (for any one month) of original sewage being 39 degrees in February and December, with temperature of effluent raised to 43 degrees and 47 degrees respectively for same months.

Other experiments by the same authorities show the same results, with some cases of a slight fall in temperature.

In the Wauwatosa plant described in Mr. Alvord's paper, temperatures were taken during the cold spell of December, 1901, with the following results: Temperature of air outside, about–4 degrees

Fah.; original sewage entering septic tank 48 degrees, in the controlling chamber between septic tank and sand beds 47 degrees, and entering creek at final outlet 44 degrees; a total loss of 4 degrees in extremely cold weather.

Therefore it seems to the writer beyond question, that no fear need be entertained of any serious trouble in operation of the septic purification plant due to cold weather in this climate. There is no doubt but that cold weather makes bacterial action more sluggish, but at the temperatures above shown the action will still continue at a rate sufficient for good purification.

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